Pestic. Sci. 1997, **50**, 183–186

Insecticide Resistance in Field Strains of *Pectinophora gossypiella* (Saunders) in China and Effect of Synergists on Deltamethrin and Parathion-methyl Activity

Li Xianchun,[1]* Wang Yinchang,[1] Zhang Qiansong,[1] Yu Ganjun,[2] Zhang Dunyang,[2] Yang Yantao,[3] Zhang Zhi,[3] Zhang Jianping,[3] Luo Shoushan,[4] Chen Caixia[4] & Ding Shiyin[5]

[1] Department of Plant Protection, Nanjing Agricultural University, Nanjing 210095, P. R. China
[2] Plant Protection Station of Jiangsu Province, Nanjing 210037, P. R. China
[3] Plant Protection Station of Tongzhou County, Jiangsu Province, P. R. China
[4] Plant Protection Station of Cixi County, Zhejiang Province, P. R. China
[5] Anqing Institute of Agricultural Science, Anhui Province, P. R. China

(Received 11 November 1996; accepted 3 March 1997)

Abstract: Filter-paper residual toxicities of some insecticides used extensively in China were determined during 1994 using newly hatched (within 30 min) larvae of four *Pectinophora gossypiella* (Saunders) strains. The strains were field collections collected in the Yangtze River cotton-belt areas. Compared with the susceptible laboratory strain from Qunli (Lishui County, Jiangsu province), the four field strains from Anqing (Anhui province), Jiangling (Hubei province), Cixi(Zhejiang province) and Tongzhou(Jiangsu province) had developed 185-, 6·7-, 698- and 249-fold resistance, respectively, to deltamethrin. Cixi and Tongzhou field strains had also developed 103- and 94-fold resistance to fenvalerate, and 10- and 3·6- fold resistance to parathion-methyl. Percentage of survivors at diagnostic dosage for deltamethrin showed that the strains from Anqing, Jiangling, Cixi and Tongzhou had 87·2, 18·3, 90·1 and 74·6% resistant individuals respectively. Cixi and Tongzhou field strains had 88·9 and 65·3% resistant individuals after application of parathion-methyl, which was consistent with the corresponding resistance ratios. Studies of the effect of synergists piperonyl butoxide (PBO), triphenyl phosphate (TPP) with deltamethrin and parathion-methyl in Cixi, Anqing and Tongzhou field strains suggested that metabolic resistance mechanisms such as carboxylesterases (CarE) and mixed function oxygenases (MFO) were involved in parathion-methyl resistance, but not in deltamethrin resistance.

Pestic Sci., **50**, 183–186, 1997
No. of Figures: 0. No. of Tables: 3. No. of Refs: 4

Key words: *Pectinophora gossypiella*, deltamethrin, parathion-methyl, insecticide resistance

* To whom correspondence should be addressed.

 Pestic. Sci. 0031-613X/97/$17.50. Printed in Great Britain

1 INTRODUCTION

The pink bollworm, *Pectinophora gossypiella* (Saunders) is a major cotton pest in the Yangtze River cotton-belt areas of China. Control of *P. gossypiella* has been accomplished chiefly by insecticides such as organophosphates and pyrethroids, and some populations have developed resistance to DDT, fenvalerate, deltamethrin and parathion-methyl.[1–3]

Managing resistance requires a knowledge of the individual resistant frequency, distribution and resistance mechanisms that exist throughout the cotton-growing regions. Here we report results of our study of resistance monitoring and synergism of deltamethrin and parathion-methyl in *P. gossypiella* field strains from the Yangtze River cotton-belt areas during 1994.

2 MATERIALS AND METHODS

2.1 Chemicals

Technical grade samples of deltamethrin (98%, Roussel Uclaf), fenvalerate (98%, Sumitomo), parathion-methyl (80%, Suzhou Chemical Group) were tested. Piperonyl butoxide (PBO; 90%, Aldrich Chemical Company, Inc.), triphenyl phosphate (TPP; Shanghai chemical reagent plant) were evaluated as synergists of insecticide toxicity.

2.2 Insect strains

Four field strains from the Yangtze river cotton-belt (Jiangling—upper region, Anqing—middle region, Tongzhou and Cixi—lower region) and one susceptible strain were tested. All field strains were kept in a climatic chamber at 28°C and a photoperiod of 16 : 8 h (L : D) with larvae-infested flowers. Newly hatched larvae (within 30 min) of F1 generation of field strains were used for toxicity studies.

2.3 Bioassay

The toxicity and survival percentage of newly hatched larvae at the diagnostic doses of insecticides were determined using filter-paper residue tests as described by Li.[1] Serial dilutions of technical grade insecticides in acetone were prepared such that each was one-half of the previous concentration. Two millilitres of insecticide solution (for treatment) or acetone (for control) was sprayed onto a sheet of filter paper (16 × 16 cm) using a Potter Tower. The treated filter paper was folded up into a box with a hole so that its surface coated with insecticide solution or acetone was turned inward. About 20 neonates were put into the filter paper box through the hole and left for 15 min, then transferred with a pen brush into a glass pot containing artificial diet. The pots were held at a temperature of 28°C under constant illumination of 130 lux. Mortality was assessed after 6 h. Five replicates (each of 20 larvae) were used for each treatment and control. Dose–mortality regressions were estimated by probit analysis. Resistance ratios at LC_{50} and survival percentage at diagnostic doses were considered to be two indicators of resistance.

3 RESULTS AND ANALYSIS

3.1 Susceptibility of the susceptible laboratory strain from Qunli

Susceptibility to four insecticides of the susceptible laboratory strain of *P. gossypiella* from Qunli (Qunli strain) is shown in Table 1. The LC_{50} toxicity order is deltamethrin > methomyl > fenvalerate > para-thion-methyl, but this is not consistent with that at LC_{99}. In general, we selected the LC_{99} as the diagnostic dose used for detecting the frequency of resistant individuals in field strains.

TABLE 1
Susceptibility to Four Insecticides of Newly Hatched Larvae of Susceptible Strain of *Pectinophora gossypiella* from Qunli (Jiangsu Province) and the Diagnostic Doses Used for Testing Field Strains

Insecticide	*Number*	*Baseline*	LC_{50} (95% FL) ($mg\ ml^{-1}$)	LC_{99} (95% FL) ($mg\ ml^{-1}$)	χ^2
Deltamethrin	600	$y = 7{\cdot}882 + 1{\cdot}470x$	0·0120 (0·010–0·014)	0·4188	2·879
Fenvalerate	600	$y = 6{\cdot}2614 + 1{\cdot}2217x$	0·092 80 (0·0898–0·0959)	7·4413	0·82
Parathion-methyl	500	$y = 8{\cdot}163 + 4{\cdot}794x$	0·2190 (0·206–0·2327)	0·6693	3·982
Methomyl	500	$y = 6{\cdot}6118 + 1{\cdot}4756x$	0·0808 (0·0787–0·0831)	3·0492	0·726

TABLE 2
Susceptibility of *Pectinophora gossypiella* to Deltamethrin, Fenvalerate and Parathion-methyl in Different Regions of the Yangtze River Cotton-Belt (1994)

Insecticide	*Strain*	*Regression line*	LC_{50} (95% *FL*) (*mg ml*$^{-1}$)	*RR*[a]	R_f [b] (%)
Deltamethrin	Qunli (ss)	$y = 7{\cdot}8820 + 1{\cdot}4700x$	0·012 (0·010–0·014)	—	—
	Jiangli	$y = 6{\cdot}1884 + 1{\cdot}0863x$	0·0806 (0·0785–0·0827)	6·7	18·30
	Anqing	$y = 4{\cdot}0816 + 2{\cdot}6451x$	2·2244 (2·1032–2·4115)	185·4	67·1
	Tongzhou	$y = 4{\cdot}3316 + 1{\cdot}4057x$	2·9887 (2·8729–3·1091)	249·1	74·59
	Cixi	$y = 2{\cdot}6100 + 2{\cdot}5883x$	8·3828 (8·1389–8·6287)	698·6	90·10
Fenvalerate	Qunli (ss)	$y = 6{\cdot}2614 + 1{\cdot}2217x$	0·0928 (0·0898–0·0959)	—	—
	Tongzhou	$y = 3{\cdot}8201 + 1{\cdot}2497x$	8·7926 (8·6268–8·9616)	94·7	ND[c]
	Cixi	$y = 3{\cdot}8645 + 1{\cdot}1560x$	9·5997 (8·240–11·1838)	103·5	ND[c]
Parathion-methyl	Qunli	$y = 8{\cdot}163 + 4{\cdot}794x$	0·2190 (0·206–0·232)	—	—
	Tongzhou	$y = 5{\cdot}4907 + 4{\cdot}7506x$	0·7883 (0·7705–0·8065)	3·6	65·29
	Cixi	$y = 3{\cdot}7400 + 3{\cdot}7243x$	2·1793 (2·1268–2·332)	9·9	88·90

[a] RR resistance ratios at LC_{50}.
[b] R_f resistance frequency, i.e., survival percentage at diagnostic dose.
[c] ND no data.

3.2 Sensitivity of four field strains

Filter-paper residual toxicity test data of four different field strains of *P. gossypiella* using deltamethrin, fenvalerate and parathion-methyl are summarized in Table 2. Significant variation in levels of resistance (resistance ratios at LC_{50}, RR) and frequencies of resistant individuals (R_f) to deltamethrin, fenvalerate and parathion-methyl was revealed among field populations from different regions. From the upper to lower region of the Yangtze River cotton-belt, resistance ratios at LC_{50} ranged from 6·7 to 698-fold for deltamethrin, 94 to 103-fold for fenvalerate and 3·6 to 10·0-fold for parathion-methyl. Resistance frequencies ranged from 18·3 to 90·1% for deltamethrin and 65·3 to 88·9% for parathion-methyl. The higher resistance levels and individual resistance frequencies were found in populations collected from the lower region of the Yangtze river. The order of resistance ratios and resistant individuals' frequency is Cixi > Tongzhou > Anqing > Jiangli. Table 2 also shows that the resistance ratios and resistance frequencies of any field strain are the highest for deltamethrin, followed by fenvalerate and parathion-methyl.

TABLE 3
Effect of Synergists on the Mortality of Three Field Strains of *Pectinophora gossypiella* Using Diagnostic Doses of Deltamethrin and Parathion-methyl

	Mortality (%)					
Strain	*Deltamethrin*	*Deltamethrin +PBO*	*Deltamethrin +TPP*	*Parathion-methyl*	*Parathion-methyl +PBO*	*Parathion-methyl +TPP*
Cixi	9·9	16·9	14·6	11·1	6·4	79·4
Anqing	32·9	38·4	35·3	36·1	100·0	100·0
Tongzhou	25·4	27·5	21·8	34·7	72·3	100·0

3.3 The effect of synergists on the toxicities of deltamethrin and parathion-methyl

Studies of the effects of synergists on the mortality of three resistant field populations at diagnostic doses of deltamethrin and parathion-methyl were conducted to obtain information about resistance mechanisms (Table 3). In the three resistant field strains tested, piperonyl butoxide (PBO) and triphenyl phosphate (TPP) did not show a significant synergistic effect to deltamethrin. In contrast, however, TPP produced a significant synergistic effect with parathion-methyl in all of the three field strains, but PBO produced a significant effect with parathion-methyl only in Anqing and Tongzhou field strains.

4 DISCUSSION

Results of our survey indicate that insecticide resistance was present in *P. gossypiella* field populations in the Yangtze River cotton-belt during 1994. We detected variations in RR and R_f to insecticides among pink bollworm populations from different provinces. The highest RR and R_f to insecticides was found in the lower region of Yangtze River, followed by the middle and upper regions. This can be explained by the different amounts of insecticides used in these regions. The results also show that the resistance to pyrethroids is more serious than that to organophosphates. This seems to be related to the more frequent use of pyrethroids in recent years. Results of our experiments with synergists (PBO and TPP) tested against three resistant field strains suggested that carboxylesterase (CarE) and mixed function oxygenase (MFO) systems could be involved in resistance to parathion-methyl, but neither MFO system nor CarE is related to resistance to deltamethrin. Osman *et al.*[4] found that PBO and DEF only produced less than 2-fold synergism to permethrin in the Yuma field strain. Permethrin resistance in pink bollworm adults may be mainly conferred by non-metabolic factors such as *Kdr* gene and reduced penetration. Obviously, Osman's results with adults are similar to ours with newly hatched larvae.

REFERENCES

1. Xianchun, L., Yingchang, W., Zhaojun, H., Mo, W., Shiyin, D., Xihua, D., Shoushan, L. & Caixia, C., Newly hatched larvae for monitoring insecticide resistance in the pink bollworm. *Acta Phytophylacica Sinica*, **22** (1995) 85–90.
2. Zhangfa, Y., Zhongxian, L. & Guangren, S. T., A preliminary survey of fenvalerate resistance in *Pectinophora gossypiella* in Zhejing province. *Pesticide*, **29**(3) (1990) 14–15.
3. Wengu, L., Yiping, L., Changben, H., Shoushan, L., Yongjiang, X., Zhongxian, L. & Zhangfa, Y., Field monitoring for insecticide resistance in pink bollworm moth (Lepidoptera: Gelechiidae) with pheromone traps. *Acta Phytophylacica Sinica*, **19** (1992) 277–82.
4. Osman, A. A., Watson, T. F. & Sivasupramaniam, S., Susceptibility of field populations of pink bollworm (Lepidoptera: Gelechiidae) to azinphosmethyl and permethrin and synergism of permethrin. *J. Econ. Entomol.*, **84** (1991) 358–62.